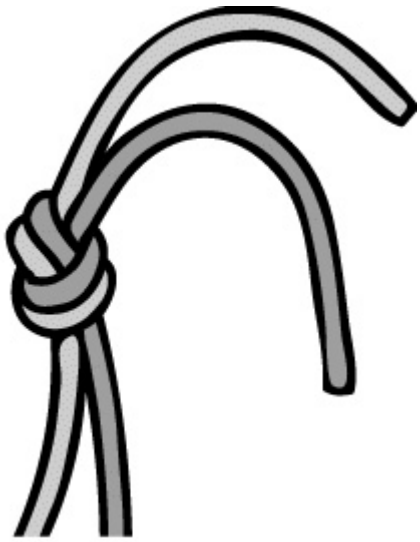
Rope and Gear Testing

Pull Tests of the "Euro Death-Knot" - 11/9/99



The flat overhand bend (or "Euro Death-Knot") is widely used for joining two rappel ropes together. Because of its asymmetrical profile, the knot tends to rotate away from the rock. The flat side lays against the rock, which makes the knot pull smoothly across edges. To tie it, lay the two ends of the rope together, pointing in the same direction. Form the overhand knot in both ropes at the same time. Pull the knot *tight*, leaving long tails. (Recommendations vary - most people suggest at least a foot of tail). Some people tie a figure-eight instead of an overhand. Some people use this knot for other purposes, such as joining two ends of a tied sling.

The failure mode of this knot is to invert (flip / capsize / roll). This leaves topologically the exact same knot, just with shorter tails. You can observe this yourself. Tie a loose figure-eight knot and pull (using a figure-eight makes it easier to flip). You'll have to help flip it around with your hands. If you do this enough times, you can make the knot roll all the way off the ends of the ropes, and you've got a failure.

I got interested in testing this knot after I saw other climbers using it - and after we (SLCSAR) were called to a climbing accident at Storm Mountain, Big Cottonwood Canyon in 1995 caused by a failure of this knot. These climbers had used the flat-figure-eight to tie slings in webbing. The knot failed during a rappel, causing the climber to fall about 40 feet. I know of three other accidents likely caused by flat-knot failures.

5/21/2002 Flat-figure-eight. Ross Tamin fell 180 feet and died on Spaceshot, Zion NP. See accident report from rec.climbing, and 2003 Accidents in North American Mountaineering (ANAM).

9/12/1997 Flat-overhand. Karen Turk fell 30 feet on the Guide's Wall, Grand Teton NP. See a detailed report by ranger Mark Magnuson, and 1998 ANAM.

10/12/1994 Flat-figure-eight. Imtiaz Lahlji fell 60 feet and died at Seneca Rocks. Reported in 1995 ANAM.

About the testing:

The testing below is a quick look to explore some of the variables I was interested in - knot preloading, rope elasticity, diameter, age, clean/dirty, dry/wet, etc. I did these tests in my front yard with a come-along and a calibrated 10,000 lb load cell. Tests 1-17 are either the flat-overhand or the flat-figure-eight. All tails are at least one foot long. The last three tests (#18, #19, and #20) are on double fisherman's knots - pretty much the gold standard for comparison. For #19 and #20, the double fisherman's is loose and mis-tied in every way I can think of that you could still barely call it a double fisherman's knot - definitely the worst excuse for a DFK I've ever seen. All pulls are on a single strand of rope (as opposed to a loop of rope), with a figure eight on a bight at each end.

In the table below, I have used the terms "capsized" and "rolled". The overhand and the figure-eight each behave slightly differently when they flip. Topologically, the knots are doing the exact same thing, but visually they're a little different. The figure-eight makes an obvious, visible flip (the same as when you flip it with your hands). The overhand squirms and then twists around an axis perpendicular to the loaded ropes. For either knot, I recorded an "event" any time the load went *down* by a few hundred pounds or

more as I pulled.

I do not think that there's an easy definition of the strength of the flat-knots. *Most* of the time, if the tails are long enough, the process of repeated flips stops at some point and the knot cinches tighter and then holds until the rope breaks. In my testing, this often happened just as the knot was about to run out of tail. Since this process is so uncertain, I regard the force at the *first* flip as the failure load for the knot. I have seen other test data published which simply lists the strength (force at rope-failure) of the flat-knots. I think this is extremely misleading.

Arguments in favor of the flat-overhand:

"The risk of getting a rope stuck on a rappel (using some other knot) exceeds the risk of having a flat-overhand knot come untied, especially if the climber has to solo up to get a stuck rope back."

I'm not convinced. A fall on rappel is usually way more serious than a stuck rope. I've personally had ropes get stuck a handful of times. While it was annoying each time, it was never life-threatening. Usually for me, the case has been that I couldn't pull the ropes at all. Those times, it was easy to prusik back up the doubled ropes and re-rig (for a description of how to do this, see the links below.) Some of those times I've had enough foresight to have the first rappeller try a test pull, and re-rig it while the second was still at the anchor. Once, I've had ropes fall into a crack and get stuck (after pulling all the way through the anchor). In that case, I was able to lead back up on what rope I had left and get to the jam. A flat-overhand knot wouldn't have helped. I've never had ropes get stuck when I was halfway through pulling them.

In the 14 years I've been doing mountain rescue, I've only been on one rescue for a climber who fell while soloing (up from the ground!) to get a stuck rope and one rescue of climbers who were stranded mid-face by stuck rappel ropes. I've personally been on *five* rescues for falls caused by knot failure during a rappel (one flat-eight, three water-knots, and one not-knot), and many others caused by rappelling off the end of the rope or by belay errors. I'm just not seeing an epidemic of stuck ropes.

"All knots have to be tied well to work properly. The flat-overhand is no different."

Yeah - knots are typically stronger when they're tied neatly. Most knots (other than friction hitches such as kleimheist, autoblock, prusik) fail by breaking, and they break at roughly the same percentage of the rope's strength each time. Even when you tie them badly (tests #19 and #20), the consequence for most knots is just a small reduction in strength. The flat-knots fail by inverting, and their behavior is extremely sensitive to mis-tying.

"Your data shows that the knot is safe. Besides, I've been using it for years and haven't had any problem."

There's an enormous variability in the force it takes to start flipping the knot. I have no confidence that I've fully explored the parameters that affect the flipping, or that one test for each set of parameters creates much statistical confidence in the answer. As someone said, "it's not the average that's the concern, it's the standard deviation." What I do know is that I didn't find any combinations of factors for a well-dressed, well-preloaded, flat-overhand or flat-figure-eight knot with sufficient tails that would cause failure at less than body weight. I also know that millions of rappels have taken place on these knots without failures. I suspect that in each of the four accidents I mentioned above, the knots were too loose and the tails were too short, but it's also possible that they simply found a combination of rope sizes and conditions that doesn't hold as well as the ropes that I tested.

My opinions:

I have personally used the flat-overhand on some rappels where I thought pulling the ropes across an edge might cause problems. Otherwise, I use a figure-eight follow-through knot with grapevine safeties. Most of

the people I know use the flat-overhand, including Chris Harmston, who co-wrote the high-strength cord paper with me. I don't believe the flat-overhand will ever fail under body weight if it is tied well.

The flat-overhand is clearly better than the flat-figure-eight. The flat-eight is represented three-to-one in the accidents despite (to the best of my knowledge) many more climbers using the overhand. The flat-eight also starts flipping at a lower load (750 lbs vs 1400 lbs for well-tied, 110 lbs vs 200 lbs for badly tied) than the overhand, and it eats two to three times as much tail in each flip.

I think both knots are a bad choice for tying slings. Why would you need the pulling advantage of an asymmetrical knot in a tied sling? And why would you be willing to put up with the uncertainty in the strength? Tie a real knot. I use a water-knot (see my water-knot testing and cautions) for slings I plan to untie later, and a single or double-fisherman's for slings I don't plan to untie - like slings that I leave at an anchor.

I also think both knots are a bad choice for more than body-weight, for use as a moving knot during a lowering, or to hold dynamic loads. I think to use them for a rescue lowering or belay is to invite an accident. There *are* a few rescue teams who use them for lowering, and they have had no accidents yet that I know of. One team that I spoke to about my testing has now changed their protocols and discontinued their use of the knot.

Adding a safety by tying a second overhand on top of the first is probably a good idea. This likely helps prevent flipping (I haven't tested it yet). It does sacrifice some of the cleanness of the knot, but at least it's all still asymmetrical. Dan Lehman has also proposed some variations of the overhand to me that look very promising. They keep the asymmetry and are all probably much harder to flip than the overhand. If I get any spare time I will test these and post the results.

Further Reading and Test Data on flat-knots:

Preferred Knots for Use in Canyons - from Bushwalker's Wilderness Rescue Research Page. Long paper with pull-test data on a number of knots used to join ropes, including measurement of the force to drag the knots across edges. The author concludes that the flat-overhand is his preferred choice and that the flat-figure-eight is dangerous.

Chockstone Tech Tips/JoinRopes - good pictures of knots and discussion. No testing. They express a preference for the figure-eight follow-through, and show the flat-figure-eight knot with a skull-and-crossbones.

Edelrid tests - (in German, with much of it translated into English). Test data on three knots: the flat-overhand, the double-fisherman's tied as a flat-knot (photo at right from their page), and on a new type of flat-knot. He translates it as "Triple Fisherman's", but it's not. The flat-double-fisherman's didn't invert at all in his tests. Cool! People have asked me about it, but I haven't done any tests.

Abseil Knots - from NeedleSports. Pull-test data on the flat-overhand and flat-figure-eight, including data on frozen ropes. The author prefers the flat-overhand with a second overhand as a safety (he calls this the double-overhand). He calls the flat-figure-eight the "instant-death knot."

Information on Stuck Rappel Ropes:

Unsticking a stuck rope - good description of what to do when your ropes won't move, including how to get back up the doubled rope.

Returning back up your rope - good description of what to do in the worst case, where the rope gets stuck

when you're halfway through pulling it.

Tom's Pull-Test Data:

Test #	Knot	Rope 1	Rope 2	Description of Knot	Event	Load
1	Figure 8	Mammut 7/16" Static (Used)	Mammut 7/16" Static (Used)	well dressed and pretensioned - pulled separately on all 4 strands	Capsized	750 lbs
					Rope broke at knot	2520 lbs
2	Figure 8	Unknown red 11 mm Dynamic (Used)	Unknown red 11 mm Dynamic (Used)	well dressed and pretensioned - pulled separately on all 4 strands	Capsized	590 lbs
					Capsized	2280 lbs
					Rope broke at knot	2560 lbs
3	Figure 8	Unknown red 11 mm Dynamic (Used)	Unknown red 11 mm Dynamic (Used)	well dressed, but not well pretensioned - pulled 2 strands against 2 strands with about 10 lbs force	Capsized	290 lbs
					Stopped Test	2800 lbs
4	Figure 8	Unknown red 11 mm Dynamic (Used)	Unknown red 11 mm Dynamic (Used)	sloppy - crossing strands and loose	Capsized	110 lbs
					Capsized	140 lbs
					Capsized	340 lbs
					Capsized	420 lbs
					Capsized	530 lbs
					Stopped Test	2500 lbs
5	Overhand	Unknown red 11 mm Dynamic (Used)	Unknown red 11 mm Dynamic (Used)	well dressed and pretensioned - pulled separately on all 4 strands	Rolled	1400 lbs
					Rolled	1940 lbs

					Rolled	1990 lbs
					Rope broke at knot	2070 lbs
6	Overhand	Mammut 7/16" Static (Used)	Mammut 7/16" Static (Used)	well dressed and pretensioned - pulled separately on all 4 strands	Stopped Test	2540 lbs
7	Figure 8	ABC/Sterling 7/16" Static (New)	ABC/Sterling 7/16" Static (New)	well dressed and pretensioned - pulled separately on all 4 strands	Stopped Test	2500 lbs
8	Figure 8	Blue Water II+ 7/16" Static (New)	Blue Water II+ 7/16" Static (New)	well dressed and pretensioned - pulled separately on all 4 strands	Capsized	2170 lbs
					Stopped Test	2550 lbs
9	Figure 8	Unknown red 11 mm Dynamic (Used)	ABC 8mm Static Cord (New)	well dressed and pretensioned - pulled separately on all 4 strands	Capsized	1330 lbs
					Capsized	1550 lbs
					8mm broke at knot	2700 lbs
10	Figure 8	Unknown red 11 mm Dynamic (Used)	Unknown red 11 mm Dynamic (Used)	well dressed and pretensioned - pulled separately on all 4 strands - wet - soaked in bucket ~15 minutes	Capsized	470 lbs
					Rope broke at knot	2790 lbs
11	Figure 8	Unknown red 11 mm Dynamic (Used)	Unknown red 11 mm Dynamic (Used)	well dressed, but not well pretensioned - pulled 2 strands against 2 strands with about 10 lbs force - wet - soaked in bucket ~5 minutes	Capsized	290 lbs
					Rope broke at knot	2470 lbs
12	Figure 8	1" Tubular Webbing (New)	1" Tubular Webbing (New)	well dressed and pretensioned - pulled separately on all 4 strands	Webbing broke at knot	2070 lbs

13	Overhand	Unknown red 11 mm Dynamic (Used)	Unknown red 11 mm Dynamic (Used)	well dressed, but not well pretensioned - pulled 2 strands against 2 strands with about 10 lbs force	Rolled	1070 lbs
					Rolled	1120 lbs
					Rolled	1470 lbs
					Rolled	1870 lbs
					Rolled	2000 lbs
					Rope broke at knot	2100 lbs
14	Overhand	Unknown red 11 mm Dynamic (Used)	Unknown red 11 mm Dynamic (Used)	sloppy - crossing strands and loose	Rolled	200 lbs
					Rolled	370 lbs
					Rolled	1400 lbs
					Rope broke at knot	2100 lbs
15	Overhand	Unknown red 11 mm Dynamic (Used)	Mammut 8mm Static Cord (New)	well dressed and pretensioned - pulled separately on all 4 strands	Rolled	1230 lbs
					Rolled	1610 lbs
					Rolled	1930 lbs
					Rolled	1840 lbs
					8mm broke at knot	1770 lbs
16	Overhand	Unknown red 11 mm Dynamic (Used)	Unknown red 11 mm Dynamic (Used)	sloppy - crossing strands and loose	Rolled	300 lbs
					Rolled	420 lbs
					Rolled	1440 lbs
					Rolled	1520 lbs

					Rope broke at knot	1830 lbs
17	Overhand	Unknown red 11 mm Dynamic (Used)	Mammut 8mm Static Cord (New)	well dressed and pretensioned - pulled separately on all 4 strands - wet - soaked in bucket ~5 minutes	Rolled	950 lbs
					Rolled	1300 lbs
					Rolled	1160 lbs
					Rolled	1130 lbs
					Rolled	1070 lbs
					Rolled	1110 lbs
					Rolled	1200 lbs
					Rolled & Sheath broke	1460 lbs
					Rolled	1230 lbs
					Rolled	1450 lbs
					Pulled end through knot	1410 lbs
18	double fisherman's	Unknown red 11 mm Dynamic (Used)	Unknown red 11 mm Dynamic (Used)	well dressed and pretensioned	Rope broke at double fisherman's	2880 lbs
19	double fisherman's	Unknown red 11 mm Dynamic (Used)	Unknown red 11 mm Dynamic (Used)	sloppy, mis-tied, and loose	Rope broke at fig-8 knot	2580 lbs
20	double fisherman's	Unknown red 11 mm Dynamic (Used)	Unknown red 11 mm Dynamic (Used)	sloppy, mis-tied, and loose - wet - soaked in bucket ~5 minutes	Rope broke at double fisherman's	2620 lbs

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Last Updated on 6/27/07